horizontally in its vertical suspension all of the rays emerging from the projection ocular of the galvanometer are rotated horizontally by a series of quartz prisms. If it is desirable to use a kymograph in which the paper film moves vertically it is merely necessary to arrange the capsules so that the mirrors of the segment capsules tilt in the same *vertical plane* and that a vertical instead of a horizontal band of light is projected upon them.

THE METABOLISM AND TREATMENT OF RHEUMATOID ARTHRITIS. FOURTH PAPER.

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In three previous communications,[1] the writer has presented a series of 37 cases of rheumatoid arthritis in which certain laboratory and clinical findings were made the basis of a method of treatment. The method in question consists essentially in the curtailment of diet, particularly the carbohydrates and proteins, to a point of tolerance which varies with the individual. In the last studies, experiments were reported, among other data, in which it had been apparently possible to induce exacerbations, in patients previously rendered free from the disease, by the feeding of pure carbohydrate.

The present article concerns further evidence in regard to the carbohydrates and, more particularly, evidence as to the role played by the fats; together with certain other findings. A series of 11 cases is therefore presented for the purpose of illustrating dietary experiments. No cases are here reported for the single purpose of illustrating further the therapeutic effect of a reduced diet alone, although such are available, as this has been done elsewhere.[2]

The plan has been followed here, in general, of determining the customary caloric intake of the individual as a help in ascertaining the reduction in food required, as elsewhere mentioned.[3]

From the caloric intake thus determined the respective proportions of protein, carbohydrate and fat could be approximated; in some cases very closely. In nearly all cases the diets which were followed, even the unrestricted "House Diet," were prepared according to fixed formulæ in which the above proportions are definitely known.[4]

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[1] The Metabolism and Successful Treatment of Chronic Joint Disease; A Preliminary Report, Am. Jour. Med. Sc., October, 1912, No. 4, cxliv, 744; The Metabolism, Prevention, and Successful Treatment of Rheumatoid Arthritis; Second Contribution, ibid., December, 1913, No. 6, cxlvi, 895; January, 1914, No. 1, cxlvii, 111; February, 1914, No. 2, p. 265; March, 1914, No. 3, p. 423; The Metabolism and Treatment of Rheumatoid Arthritis, third paper, Am. Jour. Med. Sc., March, 1916, No. 3, cli, 351.

[2] Loc. cit.

[3] Loc. cit., number ii.

[4] Edwin A. Locke: Food Values.

In making the calculations of the proportions of carbohydrate, protein and fat in the ingested food, discrepancies sometimes occur between the caloric totals thus obtained and those calculated for the diet as a whole. These discrepancies are due to the omission from calculations of such foods as spinach, bouillon, lettuce and the like whose totals do not in these cases importantly influence the relative percentages. It will be seen that in the probationary diets and in the therapeutic diets, the proportions of the three ingredients, protein, carbohydrate and fat are practically always in such striking contrast that these discrepancies are negligible. Where more refined experiments could be conducted, these figures are exactly obtained, as in Case XLVIII.

In all of these cases, sources of possible infection had been removed before treatment was begun and all were examined for these by *x*-rays of teeth, sinuses, etc., by nose and throat specialists, by dentists, etc. In Cases XLIII, XLIV, XLV tonsillectomy was performed, on advice of the writer before considering dietary treatment.

The diagnosis of arthritis was corroborated in every case by *x*-ray pictures, taken mostly by Dr. William S. Newcomet, to whom the writer desires to express his appreciation.

Limitations of space preclude all but the barest outlines of the following cases except where a particular point is illustrated.

CASE XXXVIII.—Mrs. S., aged about fifty years, referred by the courtesy of Dr. Hamilton Levings, of Milwaukee, was admitted May 18 and discharged July 3, 1916. The patient had a life-long tendency to "rheumatism" and presented a diffuse arthritis of three years' duration. There were very little soft tissue involvement and few objective signs of arthritis, and the condition seemed to concern largely the tendons. Unsuccessful attempts were made, analogous to those to be described later, under other cases, to replace the carbohydrate largely by fat, but her digestion was unequal to the task. After various reductions and fluctuations the diet was finally reduced for a few days to a mixed[5] one of 670 calories which was followed by distinct subjective improvement everywhere, but the patient could not be maintained on such a low intake. The diet was then increased to about 1000 calories, together with cod-liver oil, and this was followed with benefit though it seems plain that this case gave a definite but only limited response. During a period of unrestricted diet lasting six weeks she grew worse, developing effusion in the capsules of the finger-joints and improved, within limits, with subsidence of the effusion when the diet was again among reduced to about 1300 calories. It is perhaps safest to include this case among those instances which clinically fail to be benefited.

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[5] By a mixed diet is meant one containing protein and fat in approximately the usual ratios, and carbohydrate in rather less than the usual ratio for the total caloric value as described in paper No. 3.

Case XXXIX.—Mrs. R., aged about fifty-seven years, and referred by the courtesy of Dr. John W. Thornton, of Wheeling, W. Va., was admitted October 15, 1915 and discharged June 3, 1916. She was a wheel-chair invalid, with muscular wasting, secondary to widespread arthritis of seven years' duration involving nearly all joints and it was long doubtful whether dietary treatment could justifiably be attempted. This case is detailed chiefly because of observations on the urine to be mentioned later. The probationary house diet yielded about 2500 calories and on November 17, 1915, she was given a mixed diet yielding about 1400 calories, of which about 400 calories came from carbohydrates, about 200 came from protein, and about 800 came from fat. Almost at once this patient showed great improvement, felt less pain and the swelling of her hands progressively subsided. A difficulty of treatment presented in her easily disturbed digestion and the necessity of keeping up her general strength and weight in view of her invalidism. Because of this her diet was frequently interrupted and it was never possible to push it vigorously.

A *résumé* of this case in April, 1917, reveals the unmistakable influence of diet in an advanced case as shown by some return of function and decrease in swelling and pain. This case is still under observation and interpretation of the end result, as limited by the above factors, must be guarded but the arthritis *per se* falls unmistakably among the types susceptible of great benefit by these measures.

Case XL.—Mrs. X., aged about fifty-eight years, referred by the courtesy of Dr. Frank B. Mitchell, of East Orange, N. J., was admitted April 12 and discharged June 3, 1916. She presented muscular pains together with an arthritis of practically all the joints of the hands. A probationary house diet yielded about 2500 calories per diem, of which about 1020 came from carbohydrates, 586 from protein, and about 633 came from fat. An attempt to feed this patient a large amount of fat was unsuccessful because of gastric indigestion, but after several modifications her diet on May 7, 1916, yielded about 1589 calories, of which about 376 came from carbohydrates, 153 from protein, and 819 from fat. This diet distinctly benefited her, but owing to her impatience the fat was first reduced, followed by reduction of the carbohydrate and protein until she was taking on May 26 about 1111 calories of a mixed diet.

On May 27 nearly every sore-point in her hands and elsewhere had improved and many had disappeared.

On June 3, the patient left the hospital prematurely against advice. Before beginning treatment her weight was increased 5 pounds by forced feeding, and on leaving the hospital it was exactly the same as upon admission.

Case XLI.—Mary B., aged twenty-nine years, a ward case, admitted April 19, 1915, and discharged January 6, 1916, had a diffuse arthritis of three years' duration incapacitating her. A reduced mixed diet of 1078 calories determined as in the other cases resulted in definite but limited improvement with loss of weight. After forced feeding and a large gain in weight she was given a diet of 1707 calories supplied by 300 grams of graham crackers, three apples, 21 grams of sugar and 5 grams of butter per diem. Practically all of the caloric value of this diet except for 120 calories was afforded by carbohydrates and she remained in active arthritis.

On December 30, 1915, this diet was changed to one yielding 1440 calories, of which about 1016 came from fat about 30 came from protein and about 378 from carbohydrate distributed as follows: Graham crackers 60 grams, 3 apples, 150 grams each, 30 grams of butter, olive oil 90 c.c.

On January 6, 1916, she insisted on leaving the hospital but applied for readmission in two days. She felt apparently quite well on leaving and on January 5 and 6 had walked considerably and freely. The objective evidence of improvement was subsidence of a fibrous nodule on the right ring finger and subsidence of the soft tissue involvement of most of the small joints. What the end-result might have been in this case cannot be prognosticated but there is no doubt as to the beneficial changes witnessed in the short period last indicated.[6]

CASE XLII.—Miss C. M., aged fifty-six years, referred by the courtesy of Dr. John H. Musser, Jr., was admitted April 28, and discharged June 20, 1916. She had suffered from "rheumatism" for forty years. For five years the hands had been progressively involved and of late the knees and feet. On the house diet she ingested about 1581 calories a day of which about 851 calories came from carbohydrates, 323 from fat and 173 from protein.

On May 7, 1916, the patient was put upon a mixed diet yielding 1720 calories of which about 402 came from carbohydrates, about 183 from protein and about 1024 from fat. Thus the proportions of carbohydrates, and fat were almost reversed. After insufficient progress, on May 23 oil and butter amounting to 643 calories in all were removed from her diet, leaving a balance of 1077.

On May 26, 1916, there was some improvement, but as she was restless and impatient the diet was further changed by removing carbohydrate and protein to the extent of 227 calories, leaving about 850 calories. There was marked improvement and on June 4 she was holding her weight surprisingly well. The diet was then reduced to approximately 700 calories, and on June 7 she was better than at any time previously there being no objective sign of inflammation anywhere.

On June 20 her condition was so much improved that she felt she could follow her profession as a piano teacher. This patient was seen by Dr. Musser on May 31 and June 13. Under protest she was allowed to follow this diet for a limited period at home under the supervision of the Social Service and was given cod-liver oil. Because of conditions at home she was unable to lead the quiet life advised and shortly had to be placed upon a larger dietary by Dr. Musser. This patient showed response to diet and became largely though not entirely free from symptoms while in the hospital where her weight fell from 128½ to 120 pounds. The end clinical result to her was *nil.*

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[6] This patient was under observation only at the early and late periods of her stay in the Hospital.

CASE XLIII.—Mrs. N., aged about sixty-four years, referred by the courtesy of Dr. Horace Jenks, was admitted May 20 and discharged June 24, 1916.

This patient suffered from an arthritis of thirty years' duration involving nearly every joint. Tonsillectomy had been of no avail. On the probationary house diet she ingested about 1800 calories per diem which were afforded in the proportion of about 600 from carbohydrate, 333 from protein and about 700 from fat.

On May 26 she was given a mixed diet of about 1800 calories of which about 407 came from carbohydrates about 183 came from protein and about 1200 came from fat.

On June 1, improvement was noted but not knowing whether the fats were delaying progress 484 calories derived from olive oil were removed bringing the caloric total down to about 1334. Her progress was steady and on June 24 the sciatica and nearly all the tender spots in the hands had cleared up. She had had almost daily headache which disappeared entirely. The improvement in this case was beyond question, and the only real difficulty was in controlling her daily life. In the hospital her weight fell from 148 to 140 pounds. It is suggested that this might have been avoided by continuing the large fat intake and devoting more time to convalescence.

CASE XLIV.—Miss D. H., aged about forty and referred by the courtesy of Dr. John H. Girvin, was admitted March 25 and discharged June 29, 1916.

The patient suffered from arthritis of five years' duration involving the shoulders and knees, and the right elbow which could not be flexed beyond a right angle. On the probationary house diet she ingested about 1700 calories daily of which about 1026 came from carbohydrates, about 380 from protein and about 300 from fat.

On April 12, 1916, she was placed upon a mixed diet yielding about 1850 calories derived in the proportions of about 402 from carbohydrates, 118 from protein and 1318 from fat. The proportions of carbohydrates and fat were thus essentially reversed, the meat protein was reduced about 60 per cent. and the total calories were increased.

On May 1 the patient had made distinct though limited progress, best evidenced by less general soreness and increase of function at the right elbow which moved more freely than for five months previously. She followed this diet religiously and in April, 1917, the situation could be summed up as follows: Periods of discomfort lasting for some days would be followed by weeks of bienaise in which she would be nearly free from all pain or stiffness. The periods of exacerbation were marked by much less severe pain than she had suffered nearly constantly before treatment; and since treatment was begun the function of her right elbow had slowly but steadily increased. Particularly at night had pain been substantially modified and while she was not well it was clear that she had made unmistakable progress. During treatment the patient was given cod-liver oil. On admission and on discharge from the hospital she had a distinct secondary anemia, but in October, 1916, her blood count was normal. While in the hospital on the diet her weight fell from 114 to 105 pounds, from which it climbed to 112 pounds in January, 1917.[7]

Case XLV.—Mrs. M. W., aged about thirty-eight, referred by the courtesy of Dr. H. R. Wharton, was admitted January 24 and discharged June 26, 1916. This patient was anemic and suffered from a violent arthritis of about nine months' duration involving hands, knees and feet. Upon a probationary house diet the patient ingested about 2000 calories per diem yielded in the proportions of about 400 calories from protein, 1140 from carbohydrates and 602 from fat. On April 19, 1916, she was placed upon a mixed diet yielding about 2100 calories, of which about 488 came from carbohydrates, 233 from protein and 1400 from fat. The proteins were thus reduced about 50 per cent., the carbohydrates about 60 per cent. and the fats increased by about 100 per cent. A distinct improvement was noticeable, which with fluctuations continued until June 1, when it became less obvious. As a test of the value of fat, the bread in her diet was reduced by 60 grams a day which cut the caloric total down to about 1940.

On June 8 there was distinct improvement and the fingers changed their shape because of subsidence of inflammation. Although the evidence was not complete it strongly suggested that fat was the least harmful of the three dietary ingredients in this case. The loss of weight in the hospital was from 118 to 113 pounds. Improvement was maintained in January, 1917, as reported by letter.

Case XLVI.—Mrs. S., aged about fifty-two years, referred by the courtesy of Dr. S. McC. Hamill presented an arthritis of several years' duration involving all terminal finger phalanges. During the probationary diet she ingested an average of about 1723 calories, of which roughly 1000 calories came from carbohydrates, 400 from protein, and 275 from fat. She was then placed upon a mixed diet yielding about 1800 calories of which about 450 came from carbohydrates, 150 from protein and 1200 from fat.

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[7] This case illustrates the time sometimes required for benefit to become established and also the importance of maintaining conditions invariable in such instances.

The figures in this case are not as accurate as in cases treated at the hospital as she weighed her food herself, under instruction but the respective proportions of the three food ingredients are correctly represented. She improved from the start and in two months all tender points were greatly improved and most of them had disappeared. The subsequent control of this patient was not satisfactory and she later disappeared from observation. Her loss of weight was from 225 to 205 pounds. She was seen by Dr. Hamill in June, 1916.

CASE XLVII.—Miss M. S., aged about fifty years, referred by courtesy of Dr. Stewart Rodman, was admitted November 2, and discharged November 18, 1916. This case warrants greater detail and presented an arthritis of knees, hands, and jaws, with pain in muscle groups, dating back five years. On the probationary house diet she ingested about 2400 calories of which about 1200 came from carbohydrates, 215 from protein and about 900 from fat, leaving a small difference attributable to unreckoned calories from spinach, soup, etc.

On November 13th, she was put upon a mixed diet yielding about 2450 calories of which about 588 came from carbohydrates, 130 from protein and 1719 from fat. Benefit from this dietary was unmistakable and most gratifying. She progressed steadily and on December 17 was relieved of about 85 per cent. of her original symptoms. In fact, whereas she walked previously with much difficulty, could not get down upon her knees, etc., she was then walking as much as two miles a day with entire comfort. She still had occasional symptoms such as stiff neck in the early morning which would last for half a day, or a temporary exacerbation in one joint, but only one conclusion was possible as to her general condition. A most interesting feature is the fact that in the period during which she followed the therapeutic diet her weight rose from 113½ to 116½ pounds a clear gain of 3 pounds. This was the first instance in which this has occurred in the writer's experience. This experiment shows not only that fat may sometimes be very well borne by these cases; and that in view of the reversal of the proportions of carbohydrate and fat in this case the harmful role of the carbohydrate becomes additionally evident; but it shows also that in selected instances it is possible adequately to maintain nutrition or achieve a gain in weight while the harmful elements in the diet are eliminated; no fat absorption experiment was performed but the stools showed no gross evidence of free oil. The gain in weight is substantial evidence of large, if not complete utilization of the ingested fat.

CASE XLVIII.—Miss M. C., aged twenty-two years, referred by the courtesy of Dr. James E. Talley, was admitted November 12, 1916, and presented an arthritis of three years' duration involving the ankles, hands and wrists. This case was of great interest and yielded definite experimental data. The patient had been thoroughly examined for infectious foci and tonsils and several teeth had been removed without improvement eight months earlier. The probationary house diet yielded 1370 calories. On December 10 she was placed upon a diet of 1396 calories, consisting of 334 grams of graham crackers and 10 grams of butter per diem, of which about 924 calories came from carbohydrates, 123 came from protein and about 349 came from fat.

On December 20 she was worse and had lost 1½ pounds.

On December 21 the experiment was started of greatly reducing her carbohydrates, keeping the protein about the same and increasing the fat to make the total caloric intake as high as before. Obviously if she improved on this diet it would indicate that the fat could be well borne and, further, that the carbohydrates were harmful. She was therefore started upon a diet consisting of 136 grams of graham crackers, 5 tablespoonsful of olive oil and 30 grams of butter per diem yielding about 1423 calories.

On December 24 there was distinct improvement but on December 27 she was still losing weight. In reducing the graham crackers from 308 to 136 grams the protein had been reduced by about 17 grams. In order to make up this protein deficit as a possible cause of improvement she was given three eggs a day in addition which yielded about 20 grams of protein and about 18 grams of fat making an increased total caloric value of 1675, of which about 408 calories came from carbohydrates, 135 from protein and 1132 from fat, total 1675. This was more in calories than she ingested on the house diet. There was no gross evidence of free fat in her stools and as evidence of the degree to which she had utilized the fat of her food can be mentioned her weight which rose upon this last diet from about 90 to 94 pounds.

On February 7, 1917, she was 95 per cent. relieved of all true arthritic symptoms, could walk well and close her hands well. There was distinct dimpling over all of the previously inflamed phalangeal joints, which were not tender to pressure, about the only remaining symptom being some pain on lateral motion of one foot which was pronated and rigid from faulty mechanics but had nevertheless shared the great improvement.[8]

In the work last reported attention was called to the fact that contemporaneously with natural or induced exacerbations of the disease there seems to be a tendency for the urine to show a decreased acidity as measured by the hydrogen-ion concentration. The statement was also made that these findings needed corroboration for a longer series before they could be accepted as established. These observations have now been extended and it may be said that whereas this tendency toward a decreased acidity seems to be present in some cases, it is by no means always so. It apparently bears no necessary relation to subjective exacerbations alone.

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[8] Condition excellent, and weight 97½ pounds on April 19, 1917.

Observations on the hydrogen-ion concentration were made for long periods in Cases XLI, XLIV, XL, XLII, XLVI, XLV, XXXIX, and XLIII but significant changes were observed in two only and in one case notably, XLIV, the hydrogen-ion concentration maintained a surprising concentration throughout notwithstanding marked fluctuations in the subjective sensations. None of these cases showed any striking objective fluctuations, etc., which may explain this constancy.[9] The cases above examined were all upon fixed* and constant diets. With the idea of obtaining some picture of the metabolism as a whole at the time of an exacerbation accompanied by a drop in urinary acidity certain observations were conducted in Cases XXXIX and XLV. The results are given in the following figures. The hydrogen-ion concentration was determined according to the methods of Palmer & Henderson.[10]

The ammonia was determined by Folin's method, the nitrogen by the Kjeldahl method, the total acidity of the method of Adler and Blake[11] and the uric acid by the Folin-Shaffer method.

CASE XXXIX.

	P_H.	NH_3	NH_3 N. as per cent. of total N.	N.	
Jan. 11	6.15	..	..	..	Well.
12	6.15	0.2883	6.45	3.6803	Well.
13	6.7	0.1958	4.11	3.9084	Sick.
14	6.5	0.2082	4.7	3.7142	Well.
15	6.5	0.1763	4.14	3.5078	Well.
16	6.3	0.1926	4.62	3.4362	Well.
17	6.5	0.2633	6.28	3.4437	Well.
18	6.85	0.1905	4.36	3.5959	Sick.
19	6.7	0.1922	4.21	3.7585	Better.
20	6.7	0.1926	4.36	3.6382	Better.
21	6.15	0.2758	6.15	3.6909	Gastro-intestinal disturbance, joints pretty well, however.

It will be seen from the figures that in each case they reflect a drop in the hydrogen-ion concentration contemporaneously with the exacerbation; this occurring twice in each case during the period of observation. In Case XXXIX the ammonia curve followed in general that of the hydrogen-ion concentration. The nitrogen behaved oppositely rising where the others fell and *vice versa*. In Case XLV much the same situation obtained; the total acidity and uric acid also following in general the curve of acidity.

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*The drop in acidity may be referable to conditions accompanying effusion or other results of inflammatory processes.

[10] Walter W. Palmer, Lawrence J. Henderson: Clinical Studies of Acid Base Equilibrium and the Nature of Acidosis, Arch. Int. Med., August, 1913, xii, 153–170. The notation used signifies the logarithm of that number which expresses the actual acidity in terms of hydrogen-ion concentration; the logarithm decreases as the acidity increases and *vice versa* and the minus sign is omitted. It should be here stated that the logarithmic figures do not portray graphically the differences in reaction of the urine, as a drop from No. 7 to No. 4 in the scale of eleven flasks, three members of the series, is indicated merely by the change from 6 to 7 in the logarithm.

[11] Arch. Int. Med., 1911, vii, 479.

CASE XLV.

	P_H.	NH_3	NH_3 N. as per ct. of total N.	Total acidity.	N	Uric acid.	
April 22	6.3						Well.
23	6.5						Well.
24 (1870 c.c.)	6.15	0.2034	3.2	269.2c.c. $\frac{1}{10}$ N.HCl	5.2360	0.2138	Well.
25 (2050 c.c.)	6.85	0.1952	3.055	176.4	5.2508	0.1576	Exacerbation.
26 (1930 c.c.)	7.0	0.2362	3.667	206.5	5.2959	0.1483	Still sore.
27 (1980 c.c.)	6.85	0.2154	2.961	186.0	5.9875	0.1141	About the same or slightly better.
28 (1880 c.c.)	6.85	0.2015	3.068	176.9	5.4745	0.1178	About the same.
29 (1615 c.c.)	6.5	0.2196	3.609	226.0	4.8837	0.1846	Better; less pain everywhere.
30 (1695 c.c.)	6.4	0.2305	3.844	254.1	4.9358	0.1938	Better.
May 1 (1635 c.c.)	6.5	0.2001	3.228	256.6	5.1274	0.1349	Feels pretty well.
2 (1800 c.c.)	6.85	0.1958	3.263	142.2	4.9392	0.2295	Very well. Drop unaccounted for
3 (1534 c.c.)	6.5	..	..	..	..	..	Stomach slightly upset but feels pretty well as to joints.
4	6.5	..	..	..	..	..	Well.
5	6.2	..	..	..	..	..	Well.
6	6.85	..	..	..	..	..	Exacerbation.
7	6.85	..	..	..	..	..	Exacerbation.

In Case XLII it was noteworthy that she withstood remarkably well the several low diets upon which she was placed holding her weight surprisingly as have other cases previously mentioned and in order to obtain a reflection of her nitrogen loss, a nitrogen balance experiment was performed upon her when she was taking a mixed diet of about 700 calories per diem as per the appended case history but it reflected nothing out of the ordinary. In seven days her nitrogen balance was as follows: Nitrogen outgo, 21.99; nitrogen intake, 16.87; nitrogen loss (urinary), 5.04.

In view of the experiments previously reported in which it was apparently possible to induce exacerbations in cases of rheumatoid arthritis, previously rendered free or nearly so from symptoms, by the ingestion of cane sugar, experiments were conducted upon the carbondioxide tension of the alveolar air in a series of normal and diseased subjects with the idea of determining any marked abnormality in the rate or degree of utilization of carbohydrate by the diseased subject. Four control cases and five diseased subjects were studied two of the latter being in active arthritis and three of them well. The plan of procedure was to determine the carbon dioxide tension in the early morning upon an empty stomach, then to feed pure carbohydrate in the form of cane sugar in amounts varying from about 200 to 300 grams according to the capacity of the individual and then to watch the carbon dioxide tension at intervals of about twenty minutes throughout its rise and until it had returned to normal. This whole procedure occupied at least five hours and sometimes eight. The method used was the Plesch method as previously reported.[12] In addition some observations were made with the Haldane method using a valve, somewhat as suggested by Boothby and Peabody.[13]

In general the former method was the more dependable of the two. It was found in working with clinical subjects, especially beginning upon a fasting stomach, that the reliability of the determinations was influenced by the fatigue of the patient even when the latter was accustomed by repetition to the experiments. The aberent figures occasionally introduced were sometimes as widely fluctuating as those due to the rise in carbon dioxide tension and care was necessary to avoid misinterpreting them.

A series of 26 experiments was carried through *in toto*, some being repeated on the same subject. In some subjects consecutive uniformity was impossible. The following figures are from a normal case and one in active arthritis respectively:

NORMAL CASE A. F., NOV. 11, 1916:

Before sugar:			
10.10 A.M.	45.806	M.M.	CO$_2$
10.20 “	44.299	“	“
10.41 “	45.445	“	“
10.57 “	44.650	“	“
11.46 “	started sugar 287 gms.		
After sugar:			
12.30 P.M.	45.096	M.M.	CO$_2$
12.55 “	44.156	“	“
1.42 “	44.879	“	“
2.20 “	47.698	“	“
2.45 “	46.180	“	“
3.00 “	50.213	“	“
3.20 “	46.890	“	“
3.40 “	47.107	“	“
3.55 “	45.589	“	“
4.15 “	45.289	“	“

CASE XLVIII, ACTIVE ARTHRITIS, NOV. 30, 1916:

Before sugar:			
8.45 A.M.	34.361	M.M.	CO$_2$
9.5 “	33.649	“	“
9.30 “	35.499	“	“
10.4 “	started sugar 234 gms.		
After sugar:			
10.40 A.M.	36.175	M.M.	CO$_2$
10.50 “	34.327	“	“
11.00 “	35.109	“	“
11.25 “	35.602	“	“
11.40 “	38.663	“	“
12.00 M.	34.043	“	“
12.15 P.M.	36.175	“	“
12.50 “	34.683	“	“
1.20 “	34.374	“	“
1.45 “	35.368	“	“
2.10 “	34.019	“	“

Inspection of the figures shows that no immediate difference in the effects of large amounts of pure carbohydrate when ingested by normal and by diseased subjects is reflected in the carbon dioxide tension, at least under the conditions of experiment.

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[12] The Metabolism and Treatment of Rheumatoid Arthritis, third paper.

[13] A Comparison of Methods of Obtaining Alveolar Air, Arch. Int. Med., March, 1914, xiii, 497-506.

It is a pleasure to acknowledge the assistance of Miss E. C. Titlow in making the observations on alveolar air.

DISCUSSION. Consideration of the above cases reveals some interesting points. In the first place it is clear that the ingestion of fat by arthritic cases treated in the above manner may result differently from the ingestion of carbohydrates. It has appeared from a study of the present series that fat could be ingested with benefit in larger amounts than could carbohydrate but it has remained for the last two quoted experiments to indicate this definitely. In two cases where a large amount of carbohydrate was ingested during a period in which the patient remained ill, this amount of carbohydrate was reduced by approximately two-thirds and then replaced entirely by fat. In one of these cases the protein intake was increased with the increase of fat and in the other it was somewhat reduced. Coincidentally with this change in diet there occurred in each case an amelioration of symptoms which was beyond all question and in sharp contrast to the preceding condition of health. It is of the highest interest to note that each of these cases gained weight. It might be alleged that whereas reduction of carbohydrate had been beneficial the increase in fat was not clearly so, and not even harmless, because of the possibility that it had passed through unutilized. No fat absorption experiments were carried out but it seems clear from the maintenance, let alone the gain, of weight, coincident with the sharp reduction in carbohydrate, that the fat must have been largely if not entirely utilized. These experiments indicate therefore not only that fat is much less harmful, than carbohydrate, if indeed fat per se is harmful at all, but they also additionally indicate that the carbohydrates themselves are a cause of arthritis especially since the third element of diet, protein, was actually increased in one case.[14]

In only certain selected cases where the disease is not hopelessly chronic and the age and condition of the patient are such that lessened activity of the arthritis can be clearly appreciated, can such experiments be carried out. Furthermore gastric and intestinal digestion must be quite equal to the digestion of fat in such large quantities as are necessitated in this "experimentum crucis." Again, the reduction of carbohydrate required to influence the arthritis must be relatively moderate so that the caloric value removed may be replaced by that from fat. It is also essential that the probationary unrestricted diet shall properly reflect the nutritive equilibrium of the subject and itself be not too high in caloric value for this level to be approximated later by the addition of fat.

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[14] Two other experiments in which the protein was increased by a considerable margin have since apparently further indicated this. It will be noted that there is here some evidence that a relatively minor role for evil is played by protein.

The use of fat in such large quantities is not necessarily a clinical desideratum, even when the experiment can be carried out, and was for experiment only. For the reasons above given the evidence from the series reported, although suggestive, was not conclusive as to the possibility of what could be accomplished under favorable circumstances until the last experiments. Even in the less satisfactory types, however, such as the first nine of the series here quoted it is fairly clear that fat can be used with more or less satisfaction to the nutritive necessities. The difficulty of obtaining circumstances favorable to experimentation determines the reporting of these cases now. In advanced cases such experiments are often not clear cut and it seems possible that factors other than those originally causing the arthritis enter into the problem. It would then appear necessary not only to cut off largely the supply of toxin which caused the arthritis but additionally to influence various tissue cells, particularly perhaps in the muscles, to "utilization" of these products. Thus it appears from the study of a number of cases that a diet which is beneficial at the start in a severe case and is accompanied by a loss of weight may, after a time, operate less favorably and that a still lower diet and a further loss of weight secondary to it are required before improvement is again apparent.

In these instances it is conceivable that conditions within the tissue cells, the muscles for example, may then approximate the condition of so-called "basal metabolism" or even conditions of starvation. Under such circumstances the products of normal or pathological metabolism which reach them may be better handled or removed. This has been an hypothesis in the treatment of diabetes which recently has had confirmation. The corollary to this principle possibly explains the beneficial action, within limits, of radium, arsenic, thyroid extract and *x*-ray, the tissue cells in these instances being "whipped up" to some sort of heightened metabolism or activity by these agents. Only in the event that such heightened cellular activity could keep pace with the access of fresh toxin would these agents prove of value on this hypothesis.

There can be no question furthermore from clinical grounds alone that in certain borderland cases exercise importantly influences the "rheumatic" symptoms and it is conceivable that the modus operandi here is much the same and depends upon the "utilization" of intracellular substances.

The use of diet as advocated in this condition is not indefinite as directed toward thinning the fat individuals and fattening the thin, but specifically to reduce a source of toxin. The possibility remains that in some unknown way reduction in diet may modify the flora of the intestine and that this modification may result in changes in their elaborations. There may be a reduced quantity of bacterial split products of carbohydrate and protein. Again the benefits of a reduced diet may be referable to the actual metabolism of the tissue cells themselves and the lessened demand upon them. There is strong ground for believing that whatever the mechanism within the intestinal tract this last factor also plays a definite role. Whether or no the mechanism concerned be in fact that of bacterial activity within the intestine the method described affords a means of controlling the pathological process secondary to it.

Among attempts made to determine whether bacterial activity is a factor here was the administration of capsules of trimethol a substance[15] which is alleged to inhibit bacterial activity without interference with digestion or any toxic results from the substance itself. This was given a trial in Cases XXXVIII and XLIII but with no benefit.

Certain other points deserve mention. It is interesting to note that bone changes may apparently precede the clinical symptoms of arthritis. Not infrequently the *x*-ray will show changes, along the shafts of the bones, which give no clinical symptoms and have existed presumably longer than the joint trouble of which the patient complains. In some instances showing acute involvement of the finger-joints of only one, three or four weeks' duration (Case XXXIII) *x*-ray of the phalanges may show these overgrowths and rarification which would seem to be of longer standing. Furthermore in certain cases the subject of headache, neurasthenia and other conditions not apparently related to arthritis and having no clear etiology, *x*-ray may show the same changes. In the absence of a history of arthritis or "rheumatism" this can sometimes be regarded as a symptom of an underlying disturbance having something in common with arthritis.

Some such cases treated along parallel lines have borne this out in their clinical response, and it is suggested that in such doubtful cases the *x*-ray may yield important evidence as to the nature of the underlying trouble. Again in certain cases where there is doubt as to the exact nature of an arthritis, in the knee for example; when there are no other joints involved and the process seems local; *x*-ray of the hands may show a striking and surprising degree of involvement which at once proves the arthritic process to be widespread and systemic. In such doubtful cases it is well to include routinely *x*-ray of the hands.

It is something of an argument for the identity of the several types of arthritis, atrophic, hypertrophic and mixed, that they may all respond to diet including the fibrous nodules. These last may disappear entirely. The type of arthritis which seems to respond less well or sometimes not at all to these dietary procedures is the so-called dry type[16] of primary progressive polyarthritis, involving the tendons rather than the other periarticular structures.

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[15] Thomas Leaming & Co., New York.

[16] Lewellyn F. Barker: The Clinical Diagnosis of Internal Diseases, Monographic Medicine, iv, 93 *et seq.* D. Appleton & Co., New York and London.

It is noteworthy that some cases of long standing involving clinically nothing more than the terminal phalangeal joints of the hand respond with as much difficulty as though more important joints were concerned and the whole health of the individual reduced in consequence. In other words the limited extent of an arthritis does not necessarily imply facility of treatment and conversely a widespread involvement may subside surprisingly easily.

It should be borne in mind in considering responses of only moderate degree that they occur for the most part in patients the subject of chronic arthritis, generally of poor nutrition, and in the later decades of life. It is of course precisely the most advanced and difficult cases which are most ready to take up treatment and exceptionally is there opportunity to treat arthritis unaccompanied by sequelæ.[17] It is important again to emphasize the necessity of caution in carrying out treatment along these lines, as elsewhere discussed in detail.

CONCLUSIONS. 1. Experiments are cited in which it has been possible to relieve patients of all or practically all, symptoms of diffuse arthritis by a large curtailment of carbohydrate coincidently with the ingestion of fat in such increased amounts as to make up or exceed this caloric deficit. When the protein intake has been kept approximately constant some such patients have actually gained weight while convalescing. This evidence by exclusion ascribes an injurious role to carbohydrate, is additional to that already published and is corroboratory of it.

2. It is difficult to avoid the conclusion that fat, while it cannot be used with impunity in treating these cases, plays a relatively harmless role in marked contrast to carbohydrate. It can apparently be used in many cases to meet, more or less, the loss of weight which would otherwise ensue and in certain selected cases to meet it entirely or even to cause the patient to gain weight.

3. The difference in the effects of large amounts of carbohydrate when ingested by normal individuals and by subjects of rheumatoid arthritis is not reflected in the carbon dioxide tension of the alveolar air under the limited conditions of the experiments.

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[17] The exact proportion of cases in which clinical benefit may be expected, cannot be given, but is indicated in general with some of the determining factors in the third paper, loc. cit.